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Ispol'zovaniye Donetskikh Gazovykh i Dlinnoplamennykh Ugley dlya
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UTILIZATION OF DONETS GAS COAL AND LONG-FLAME COAL FOR COKING

COAL FOR COKING

Properties of Gas Coal and Long-Flame Coal

The yield of volatile substances, as indicated in laboratory crucible coking tests, is the basic factor which determines the suitability of coal for a specific type of industrial use. The following table indicates types of coal now in use in the USSR, with characteristics of each type:

<u>Type of Coal</u>	<u>Brand Name</u>	<u>Yield of Volatile Substances Based on Weight of To- tal Combustible Mass (VS, %)</u>	<u>Characteristic of Laboratory Coke</u>
Long-flame	D	More than 42	Not caked; powdered or adhering
Gas	G	36-44	Caked, fused, some- times bulging
Steam-fat	PZn	26-36	Caked, fused, com- pact or relatively compact
Coking	K	18-26	Same as above
Steam-caking	PS	12-18	Caked or fused with variable density
Lean	T	Less than 17	Not caked; powdered or adhering

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This data shows that a wide range of coals, with a yield of more than 36 percent of volatile products in crucible coking, belongs in the categories of gas and long-flame coal. Since the yield of volatile substances is indicative of the degree of metamorphism, coals of the above types belong to very slightly metamorphosed classes. These coals are characterized likewise by a high oxygen content in the coal deposits as is indicated by the following table:

No	Seam	Type	Yield of Volatile Substances (Vg, %)	C°	Elements in Organic Mass (in %)			
					H°	N°	O°	S°
DONETS BASIN								
1	Tolstyy-17	G	37.12	84.18	5.11	1.34	8.39	0.98
2	Novyy-13	G	38.12	84.39	5.31	1.57	7.18	1.54
3	Shestichet- vertevy-11	G	37.96	82.56	5.37	1.10	9.35	1.09
4	Valyuga-11	G	41.12	80.20	4.90	1.54	11.64	1.72
5	Nikolayev- skiy-17	G	40.72	83.11	5.43	1.37	9.00	1.09
6	Nikanor-14	G	37.95	83.25	5.42	1.43	8.79	1.11
7	Almaznyy- 13	G	40.48	85.85	5.28	1.45	5.61	1.81
8	Rubezhnyy- k8	G	41.77	83.31	5.15	1.37	7.53	2.64
9	Butovskskiy- 11	G	38.46	84.90	4.86	1.63	7.32	1.29
10	Semenovskiy- k8	G	40.14	83.41	5.35	1.34	7.56	2.34
11	Smolyaninov- skiy-h'6	G	38.61	83.63	5.44	1.55	8.00	1.38
12	Kurakhovskiy- 14	D	45.63	80.57	5.29	1.63	11.37	1.14
13	I Lisichenskiy- 18	D	42.76	78.52	5.70	1.49	12.86	1.43
14	Bobrovskiy- 16	D	43.42	80.23	5.07	1.36	12.42	0.91
15	III Lisichan- skiy-14	D	45.90	77.37	5.36	1.67	14.05	1.55
16	VII Lisichan- skiy-k8	D	44.67	78.54	5.30	1.38	12.92	1.87
17	Lidiyevskiy- 14	D	44.69	79.33	5.32	1.74	11.22	2.40

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No	Seam	Type	Yield of Volatile Substances (VS, %)	C°	Elements in Organic Mass (in %)			
					H°	N°	O°	S°
<u>TKVIBULI DEPOSIT (TRANSCAUCASUS)</u>								
18	Mixed seams	G	36.43	81.39	6.55	1.52	9.60	0.94
<u>KUZNETSK BASIN</u>								
19	Mayyerov- skiy	D	43.45	83.01	6.05	2.60	7.84	0.50
20	Boldyrev- skiy	G	41.72	84.09	5.85	2.72	6.95	0.39

The very slightly metamorphosed long-flame coals are characterized by only a slight tendency to cake or complete absence of caking. In crucible coking these coals yield a powdered substance or an adhering bead. A plastometric study of coals indicates that the thickness of the plastic layer y amounts to from 0 to 9 mm; the plastometric shrinkage x amounts to 40 to 50 mm. The temperature at the beginning of the transition to a plastic state ranges from 340 to 360 degrees; the beginning of gas generation is at from 280 to 290 degrees C. The total temperature range of the plastic condition is small, amounting to 30-40 degrees.

Coking coal of this type without any admixture, even those having the greatest capacity for caking, i.e., seam kg in the Lisichanskiy region of the Donbass, results in a slightly fused solid residue which is friable and crumbles easily. The addition of fat coals (PZh) greatly increases the caking capacity of the mixture resulting in a more or less tough coke.

The above properties characterize in like measure almost every group of long-flame coal of the various coal basins and deposits, including the Tkivbuli deposit in the Transcaucasus. Therefore, from the coking standpoint, coals of this type may be regarded as uniform.

There is a very large group of gas coals which differ considerably from one another in coking possibilities. The majority of the gas coals have the following plastometric indexes: thickness of plastic layer y = 10 to 14 mm; plastometric shrinkage x = 30 to 35 mm.

The temperature at the start of transition to a plastic condition is from 350 to 380 degrees C; gas is generated at 310 to 320 degrees; the total range of the plastic condition is from 50 to 60 degrees.

When coked without admixture, gas coal yields well-formed coke of characteristic structure. Gas coal can also be coked with an admixture of coals of other types. The gas coals of the Krasnoarmeyskiy deposit of the Donbass are the most characteristic representatives of this type of coal.

A considerable group of gas coals are distinguished by a high caking capacity, approximating the indexes for PZh type coal. Examples of this are the coal in Perovichnyy seam in the region of Stalino-Makeyevka or the

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Valyuga seam in Tsentralnyy Rayon. In the Kuznetsk Basin, seams of the Baydayevskiy, Chertinskiy, Uskatskiy and Karagailinskiy deposits are also to be classified with such coal. Essentially these coals must be put into a separate group of gas-fat coals, an intermediate stage between types G and PZh.

Coal of the Leninskiy deposit of the Kuzbass is a peculiar type of gas coal, characterized by low viscosity in the plastic state. In this respect it differs greatly from the Donbass Krasnoarmeyskiy coal which is similar to it in other respects.

The different properties of individual groups of gas and long-flame coal make it necessary to work out and set up special methods for treating them. These properties also determine the most efficient methods of their utilization, adapted to the differences of the individual types.

Most of the coals in the Donbass have a high ash content -- more than 10-12 percent. This makes it necessary to clean them since the presence of mineral impurities impairs the quality and lowers the yield of products in all methods of the technological treatment of coal. This also applies in an equal measure to all groups of slightly metamorphosed coals independently of their other properties.

The groups of coal under discussion differ considerably from each other in sulfur content.

All long-flame coals of the Donbass are rich in sulfur. A number of gas coals have a low sulfur content. In deciding on an efficient method for treating these coals, their sulfur content is very important. In certain cases, such as in coking, this factor becomes decisive.

Coal reserves of these types are exceptionally important. The Donets Basin is rich in coal with a high yield of volatile substances. According to available data, 32.9 percent of all available industrial coals consist of types G and D with a yield of volatile substances exceeding 36 percent. Total reserves of all caking coals of types PZh, K, and PS exceed this figure only slightly, amounting to 38.6 percent of all coals of the Donbass. Thus the potential output of the Donbass, as far as slightly metamorphosed coals are concerned, is very significant.

The greatest accumulation of slightly metamorphosed coals of the gas type occurs in the Krasnoarmeyskiy Rayon where more than 50 percent of all G and D coal reserves in the Donbass are concentrated.

Recent investigations have shown that in a number of seams of deep strata (for example, C₂⁵) there are seams of coal of great thickness (k₅, k₇) distinguished by exceptionally low ash and sulfur content. These seams have a coking capacity both with and without admixtures. The ash of coals of Krasnoarmeyskiy Rayon is characterized by a high melting temperature (1,400 degrees and above) which makes them particularly valuable for gasification.

Representatives of gas coals in operating mines of Krasnoarmeyskiy Rayon are to be found in seams l₇, l₆, l₄, l₃, l₁, and k₈. The quality of the coals in these seams is indicated in the following table:

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Quality Indexes of Run-of-Mine Coal

Seam	Ash As (%)	Sulfur Ss (%)	Volatile Substance Vg (%)	Plastometric Coordinates		Melting Temperature of Ash in Degrees C			Ash Content in Classes of Coal	
				y	x	Start of Deformation	Start of Softening	Transition to Liquid State	As (+13 mm)	As (-13 mm)
17	14.48	1.64	37	9-12	30-35	1275	1340	1384	12.8	17.8
16	15.63	1.36	34	5-7	40-45	1426	1491	1491	15.6	15.6
14	9.59	3.15	35	9	36	--	--	--	8.7	11.1
13	25.87	3.25	38	12	31	1293	1360	1384	27.2	24.2
11	20.30	3.28	36	10-13	34-35	1320	1384	1412	17.6	27.0

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The average quality of samples of screened coal (+ 13 mm), after manual removal of stones in the mines, is characterized by these indexes: moisture content, 3 to 6 percent; ash (with reference to dry substance), 3 to 7 percent; volatile substance (with reference to total combustible mass), 36 to 37 percent; sulfur (with reference to dry substance), 1.6 percent; plastometric coordinates, $y = 13$ mm, $x = 30$ mm.

According to data of the UKhIH (Coal Chemical Institute) the following products result from coking screened gas coal:

Coke	70%
Gas	17% (360 cubic meters per ton of coal) ($Q_H = 4,000$ calories per cubic meter)
Tar	5%
Crude benzene	1.7%
Water evolved in heating and losses	<u>6.3%</u> (by difference)
Total	100%

There are large reserves of gas and long-flame coals also in the Stalino-Makeyevka and Mar'yevski areas. Here ash- and sulfur-containing seams predominate which somewhat lowers the value of the coal.

On the other hand the seams in these areas are thicker than in Krasnoarmey-skiy Rayon; they have been prospected to a greater degree, and the geographic regions have been more developed industrially. The seams in the Stalino-Makeyevka region are particularly valuable. Among them there are large numbers of low-sulfur, excellent caking coals.

Lisichanskiy Rayon of the Donbass is completely distinct belonging to the least metamorphosed long-flame bituminous coals with a yield of more than 42 percent of volatile substances. Available data indicates that coal of all seams of this region has a high ash content, the average for run-of-the-mine coal being 19.12 percent. The sulfur content too is high, averaging 4.28 percent. The ash content is considerably lowered, from 18.87 to 9.03 percent, by screening the coal and removing stones from large-sized coal. The majority of the region's seams belong to a category easily cleaned of ash.

Investigation of coking capacity indicates that seams k_9 and l_4 are best for this purpose. Coking capacity for coarse types of coal (above 3 mm) is considerably higher than for fine coal (below 3 mm) due to the effect of fusain, which has the property of sharply lowering the coking capacity. It is advisable for coking to use only sorted coal (above 3 mm) after manual and mechanical cleaning.

Products obtained in coking are as follows according to the UKhIH:

Coke	63%
Gas	22.4% (407 cubic meters per ton of coal) ($Q_H = 4,000$ calories per cubic meter)
Tar	4.9%
Crude benzene	2.0%
Ammonia	0.4%
Water evolved in heating and loss	<u>7.3%</u> (by difference)
Total	100%

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Consideration of data shows that the chief industrial regions of the Donbass are rich in deposits of slightly metamorphosed coal suitable for chemical treatment.

Transcaucasus coal deposits (Tkivbuli, Tkvarcheli) consist exclusively of coal with a yield of volatile substances exceeding 36 percent.

THE TECHNOLOGY OF COKING GAS AND LONG-FLAME COALS

1. Composition of Coal Charges

The components of the coal charge determine the selection of the coke for metallurgical or for nonmetallurgical purposes.

a. Charges for the Production of Metallurgical Coke

Since the metallurgical industry is the chief consumer of coke from Donets coal, the quality of coke will vary depending on the size of the blast furnace and the type of pig iron being produced.

Various charges have been worked out in the production in coke-chemical plants based on technological conditions in a given plant. Plant charges may differ depending on the presence of a coal-cleaning installation within the plant system and on conditions of coking (Dinas or chamotte furnaces) even when uniform types of coke are produced in these plants.

Technological conditions of coke production and its use in blast furnaces require a different charge in different plants, particularly when using gas coal as a charge component.

The use of Donets gas coal in coking charges by the coke-chemical industry of the South was started in the prewar period and was dictated by the following considerations:

(1) The operation of the coke ovens is facilitated since gas coal, as developed by the works of the Ukrainian Coal Chemical Institute, sharply reduces pressure from bulging of the charge during coking and increases the final shrinkage of the coke mass in the oven. As a result of this the ovens are better preserved and their length of service is increased.

(2) The sulfur content is lowered since gas coal with a low sulfur content is required in the first place for coking and desulfurization of gas coal during the coking process proceeds more vigorously than in the case of other coals.

(3) The output of coke gas is increased making it possible to satisfy to a large extent metallurgical requirements for high-calorie coke gas (open-hearth furnaces, soaking pits, etc.) and for other consumers. At the same time, the output of the chemical products of coking is increased and their quality is improved.

(4) The reserves of the Donbass are properly utilized because of the large gas-coal deposits, which exceed the total reserves of the chief type of coking coal (PZh, K, PS).

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Charges with a content of up to 20 percent of gas coal have been introduced into large blast furnaces. For the production of metallurgical coke, charges with the following gas-coal content can be recommended:

<u>Types of Coal (in %)</u>					
<u>Charge Type</u>	<u>G</u>	<u>PZh</u>	<u>K</u>	<u>PS</u> (caking)	<u>Comment</u>
I	15	45	20	20	--
II	20	40	22	18	--
III	25	35	20	20	Principally for plants with coal washers

Considerable experimentation has been carried on over a long period with the goal of raising the percentage of gas coal in charges and increasing gas supplies and the principal chemical products of coking.

(1) In one of the Donets coke-chemical plants with a coal-cleaning shop and chamotte coking ovens, protracted experimentation in coking was carried on with a charge with a gas-coal content of 25 percent. The following table shows the results:

<u>Type of Coal</u>	<u>Yield of Volatile Substances</u>	<u>Yield of Chemical Products of Coking*</u>			<u>Coke Gas, Cubic Meter Per Ton of Dry Coal (Q_H - 4,000 Calories/cu m)</u>
		<u>Tar</u>	<u>Ammonia</u>	<u>Crude Benzene</u>	
	<u>V% %</u>	<u>Total Organic Constituents of Coal (%)</u>			
PZh	26.08	3.74	0.281	1.226	311
G	39.15	4.90	0.433	1.380	331

* According to coking data obtained in laboratory oven

The entire plant was converted to work with the new charge and the output and quality of the coke and the chief chemical products of coking were determined. The experimental charge consisted of PZh coal, 74-76 percent, and G coal, 24-26 percent. The yield of volatile substances increased to 27-28 percent as against 24.1 percent with a normal charge. Experiments gave the following results:

(a) Gross yield of coke equalled 75.15 percent of the dry coal, i.e., 2.95 percent below the amount obtained by the plant from a charge without gas coal. It is interesting to note that with the increased yield in volatile substances one should expect the output of coke to be 3.81 percent less. The output of coarse coke (above 25 mm) was not decreased and amounted to 96.85 percent as against a usual 95.82 percent. The drum specimen (barabannaya proba) of coke varied from 318 to 323 kilograms (normally 330 to

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340 kilograms). Fracturing was reduced from 0.069 to 0.055; porosity was practically unchanged.

(b) Yield of gas (reduced to standard $Q_H = 400$ calories per cubic meter) [sic] was increased to 359 cubic meters from one ton of charge as against a normal 331 cubic meters, that is an increase of 28 cubic meters per ton. The calorific value of the gas was maintained at the normal level.

(c) The yield of coal tar was 3.51 percent of the dry charge (normally, 2.6 percent).

(d) The yield of crude benzene averaged 0.83 percent of the dry coal, increasing in individual batches to 0.95 to 1.06 percent; an increase above normal of 31.3 percent. The toluene content in crude benzene rose to 20.2 percent.

(e) The yield of ammonia was practically unchanged.

(2) Extensive operations were carried on in plants using Dinas ovens. After preliminary laboratory and semi-industrial investigations the experiment was made of converting a plant with a coal-cleaning shop to a charge containing 19-20 percent gas coal and PZh coal, which has approximately the same shrinking properties. The resulting yield of volatile matter amounted to 29.5 percent of the total combustible mass.

The drum specimen of the coke averaged 318 kilograms over a 9-day period of experimentation and on some days reached 320 kilograms as against 322 kilograms from a charge with the usual composition.

The yield of crude benzene during the operations averaged 0.965 percent, and for individual shifts and days exceeded 1.0 percent of the dry coal as against 0.88 percent for a normal charge. This conforms to the estimated increase in supplies of chemical products from the charge.

The yield of coke gas was 346 cubic meters per ton of coal (Q_H equals 4,000 calories per cubic meter). On some days it was as high as 349 to 354 cubic meters per ton.

(3) An experiment was carried on in one plant using a cleaned charge with 20 percent gas coal of a low sulfur content. The charge contained 58 percent PZh coal, 22 percent K coal, and 20 percent G coal. The yield of volatile substances from the charge was 28.5 to 29 percent of the total combustible mass. Coke obtained had the following characteristics: drum specimen, 345 to 351 kilograms; fracturing, 0.116 to 0.151. It was columnar in structure, with a silvery tint, and showed low porosity.

For a long time the same plant has used a charge consisting of 40-45 percent PZh, 25-20 percent K, 15 percent PS, and 20 percent G coal. The result of this has facilitated the removal of the coke mass from even somewhat deformed furnaces. Blast furnaces of the metallurgical plant connected with this plant operate successfully on this coke.

The yield of crude benzene during the experimentation period ranged between 0.956 and 1.025 percent of the dry coal.

(4) Recently an experiment in converting one plant with a cleaning shop to the following charge was carried out: 35 percent PZh, 30 percent K, 20 percent PS, and 15 percent G coal.

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Long-continued coking with this charge produced coke with a drum specimen of 345 to 350 kilograms and with high indexes in other physicomechanical properties.

(5) An experimental coke-chemical plant made protracted tests with different variations of uncleaned charges containing from 15 to 30 percent gas coal. The object of the work was a detailed investigation of the quality of the coke and in this connection prolonged battery coking was carried on (5 days for each variation). It was determined that the best variation of the charge was the one which contained 50 percent PZh, 10 percent K, 10 percent PS, and 30 percent G (screened) coal; the yield of volatile substances amounted to 29 percent. A drum specimen of coke ranged from 328 to 333 kilograms and fracturing varied from 0.02 to 0.109.

(6) A charge containing 15-25 percent gas coal was used for coking over a considerable period in a coke-chemical plant which supplies blast furnaces of a metallurgical plant with coke. In operating with a charge of this type the plant achieved a 10-percent increase in the gas output and a 1.05-percent increase in the yield of crude benzene. The charge was made up of cleaned and run-of-the-mine, low-ash coals.

(7) Of particular interest is the choice of a highly shrinking charge for one of the coke-chemical plants of the South, the oven chambers of which are of unusual width (300 and 350 mm). It is known that with an equal temperature of the walls, as the width of the chamber decreases, the rate of temperature rise within the coal charge is increased and the coking period is shortened correspondingly. As a result, the speed of coking in the chamotte ovens of the plant approximates the speed in Dinas ovens, a procedure which creates favorable conditions for coking a charge with a higher gas-coal content. The charge composition, as determined in tests at the plant, was extremely unusual for coke-chemical plants and is as follows: 40 percent PZh, 20 percent PS or K, 40 percent F (type G) or G (screened) coal.

The charges were made up of run-of-the-mine, low-ash and cleaned coals. The yield of volatile substances from the experimental charges reached 28-29 percent. The coke obtained from experimental charges was distinguished by a uniform grain-size composition (chiefly 80-40 mm); the drum specimen of coke amounted to 315-317 kilograms; fracturing was from 0.102 to 0.106. The coke was fed into the blast furnace of the metallurgical plant (volume 365 cubic meters). The furnace operated for a month on this coke and the following results were obtained. Coefficient of utilization of furnace volume = 0.89; consumption coefficient of coke = 0.871; fulfillment of furnace plan = 109.3 percent.

Yields of principal chemical products from the experimental charges increased sharply as against normal yield. The output of coal tar amounted to 3.7-3.8 percent, crude benzene 1.150-1.160 percent, ammonia 0.304 percent, and coke gas 340-350 cubic meters per ton of dry coal.

(8) Further increase in the gas-coal content in a charge was made possible by experimental coking in one of the coke-chemical plants of the South. During a coking period lasting 13.5 to 14 hours the following charge was coked: 20 percent PZh, 20 percent PS, and 60 percent G (screened) coal.

Yield of volatile substances from the charge was 30.6 percent of the combustible mass. Gross output of coke under industrial conditions was 74.1 percent of dry coal. Distribution of metallurgical coke (above 25 mm) was as follows: above 80 mm, 34.18 percent; 80-40 mm, 57.20 percent;

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40-25 mm, 6 percent; 25 mm, 2.62 percent. A drum specimen of coke amounted to 324 kilograms; fracturing of the coke (total) was 0.158. The coke was characterized by the uniform size of the lumps. A blast furnace (volume 683 cubic meters) operating on this coke for a period of 5 days ran smoothly and efficiently with the coke consumption index figure at 1.082, which represents 14.1 percent less than the amount consumed with usual coke.

During the period of operation with the charge mentioned above, the output and qualities of the chief chemical products of coking were determined. The yield of coal tar was 4.35 percent of the coal; the specific weight of the tar was 1.19; the content of phenols was 1.91 percent of the tar, the total yield of oils was 46.8 percent. The yield of crude benzene amounted to 1.56 percent of the coal. Total yield of coke gas was 347 cubic meters per ton of dry charge.

Composition of gas in percent is as follows:

CO ₂	C _m H _n	O ₂	CO	H ₂	CH ₄	N ₂
3.2	2.9	1.2	7.1	49.6	28.2	7.8

(9) A charge of similar content, with 60 percent of low sulfur gas coal was coked for a long time in another coke-chemical plant which lacked a coal-cleaning installation. A brigade of the Academy of Sciences USSR, under directorship of Academician M. A. Pavlov, investigated the behavior of the coke in a blast furnace (volume 930 cubic meters). Pavlov writes: "Coke with a drum specimen of 318 kilograms was obtained and the quantity of fine material after the drum test amounted to 35 kilograms. The coke had a 10.28-percent ash content and a 1.62-percent sulfur content. The productivity of the blast furnace was 960 tons with a coke consumption index of 1.119. The temperature of blasting was 570 degrees. The furnace operated smoothly without setbacks." Pavlov considers that coke from a charge containing 60 percent gas coal is completely suitable for metallurgical purposes.

The investigations listed above and plant experimentation clearly confirm the possibility of utilizing low-sulfur, caking gas coals of the Donbass (type of coal in Mine No 5/6 imeni Dimitrov) in charges of coke-chemical plants for the production of metallurgical coke. The productivity of coke-chemical plants increases considerably for tar, phenols, benzene hydrocarbons, and coke gas and, what is particularly important, the work of the coke ovens is facilitated by the fact that gas coal sharply decreases expansion pressure exerted by the charge in coking.

b. Charges for Coke Gas Plants

The principal task of coke gas plants is to obtain coke of a definite quality, differing from the usual types of metallurgical coke, in addition to the maximum possible quantity of coke gas and chemical products of coking.

Requirements regarding the quality of coke produced in coke gas plants have not yet been precisely defined. Consumers of coke may be different branches of industry (gas generators, nonferrous metallurgy, chemical industry) and public utilities. In the selection of coal to produce such coke, a considerably more extensive raw-material base can be counted upon than that for coke-chemical plants producing metallurgical coke. The principal raw material base for these plants must be slightly metamorphosed gas and long-flame coals which develop the greatest amounts of gas and other volatile products of coking.

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(1) Protracted coking was carried on under industrial conditions in Dinas ovens at one of the coke-gas plants. Here charges of the following composition, made up of run-of-the-mine, low-ash coal, were tested:

	<u>PZh Coal</u>	<u>G Coal</u>
Type I	75%	25%
Type II	85%	15%

A^S equalled 6.0 to 6.7 percent; V^S equalled 31.8 to 33 percent. The result was tough coke with a drum specimen of 301 to 305 kilograms and with a 72.7-74.5-percent yield (above 25 mm) in a standard "melom" drum, that is a sturdy, transportable product, and suitable for industrial and household uses.

The output of coke gas during the test was 325-333 cubic meters per ton of coal with Q_H = 4,202 to 4,252 calories per cubic meter; typical gas composition was as follows:

	<u>Percent</u>
CO ₂ +H ₂ S	1.6
C _m H _n	2.3
O ₂	1.9
CO	5.1
CH ₄	20.9
H ₂	58.2
N ₂	9.9
γ	0.49

Output of coke tar range from 2.9 to 3.1 percent of the coal. The specific weight of the tar ranged from 1.169 to 1.173. Phenol in the tar ranged from 1.1 to 1.2 percent. The total oil yield from the tar was 42.3 to 44.3 percent of the tar. Yield in crude benzene (in gas) was 1.1 percent of the coal.

(2) A further increase in the amount of gas coal per charge was achieved by the choice of the best ratio of various coals for coke-gas plant charges. After preliminary laboratory research, operations were continued in an experimental plant where the developed charge was coked over a considerable period of time.

The experimental charge consisted of cleaned and run-of-the-mine coal with a slight ash content: 40 percent PZh, 20 percent K, and 40 percent G coal.

The average yield of volatile matter from this charge amounted to 30.2 percent, a considerable increase over the usual norm. The yield of gas, determined by special measurements was 367 cubic meters per ton of dry

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charge ($Q_H = 4,000$ calories per cubic meter). The gas is characterized by an increased content of unsaturated hydrocarbons. Its calorific value is high.

Analysis of Gas
(in %)

$CO_2 + H_2S$	C_mH_n	O_2	CO	CH_4	H_2	N_2	Specific Weight of Gas	Q_H
2.2	3.8	1.4	5.8	25.4	51.3	10.1	0.552	4,334
2.0	2.8	1.6	5.8	26.1	53.4	8.3	0.509	4,269
2.4	3.0	1.0	5.6	24.2	56.6	7.2	0.491	4,218
1.6	2.8	1.4	4.4	22.8	58.8	8.2	0.475	4,085
1.6	2.8	1.4	5.4	25.1	53.2	10.5	0.520	4,167

The quantity of tar obtained was determined by measuring it in containers. Yield of tar was 3.73 percent of the dry coal.

The tar is characterized as follows: specific weight, 1.198; distillation by fractions: 170 to 230 degrees, 4.08 percent, 230 to 270 degrees, 6.87 percent, 270 to 300 degrees, 4.09 percent, 300 to 350 degrees, 12.39 percent, pitch, 68.68 percent.

To determine the amounts of ammonia and benzene hydrocarbons in the gas, analyses were carried out at different points of the gas conduit. Thus the yield of products was determined to be crude benzene, 1.178 percent of dry coal, ammonia, 0.323 percent of dry coal.

(3) L. M. Mayer, with associates employing the petrographic method of studying coal, established the possibility of improving the coking properties of gas coal in Mine 5/6 imeni Dimitrov by removal of the fusain-containing fractions from the coal. It has been shown by prolonged experiments that a binary mixture of gas coal, improved by removing the fusain, with fat coal of PZh type in the ratio of 70:30 may result in coke of satisfactory quality. Experimental industrial coking in one of the plants has indicated that adequately tough coke, with a drum specimen of 300-305 kilograms and suitable for various nonmetallurgical uses, can be obtained from these mixtures. Yield of chemical products of coking in this way amounted to: tar, 3.07-3.22 percent of coal; crude benzene, 1.05-1.12 percent; coke gas, 333-343 cubic meters per ton of coal. The composition of gas was C_mH_n - 2.0 percent, O_2 - 1.6 percent, CO - 6.8 percent, CH_4 - 30.9 percent, H_2 - 50.2 percent, N_2 - 8.7 percent, Gamma - 0.53 percent.

(4) Gas coal of the Krasnoarmeyskiy deposit of the Donbass is valuable raw material for coking and can be used without admixture in coke ovens. Recent laboratory and industrial coking of gas coal, with the aim of working out a technological method for coking this coal without admixture, has been carried out. The coal contained: ash, 5.5 percent, sulfur, 2.9 percent; yield of volatile substances (V₈), 40.34 percent. The coal was coked in ovens of the GIPROKOKS (State Institute for Planning Coke) system. The best coke was obtained under industrial conditions with a temperature at the heating

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partitions of 1,380 degrees on the coke side, and 1,310 degrees on the machine side. Under these conditions the temperature of 900 degrees at the center of the coke mass was achieved in the 14th hour of coking.

The physicommechanical properties of the coke are characterized as follows: drum specimen, up to 270 kilograms; yield of coarse coke (above 25 mm), 90.2 percent; coefficient of uniformity of coarse coke, 4.5; most of the coke ranges in size from 40-90 mm. It is characterized by a silvery sheen, insignificant transverse fracturing, and a highly fused state. Undoubtedly it is possible to use this coke for gasification and household requirements.

The expediency of coking gas coal without admixture is indicated by the large yield of basic chemical products. The yield of gas is 360 cubic meters per ton of coal, corresponding to a calorific value $Q_H = 4,000$ calories per cubic meter. The composition of the gas is as follows: CO_2 , 3.6 percent; C_mH_n , 4.1 percent; O_2 , 0.5 percent; CO , 5.1 percent; CH_4 , 34.2 percent; H_2 , 49.0 percent; N_2 , 3.5 percent; $\Gamma = 0.525$; $Q_H = 4,897$ calories per cubic meter.

The output of tar is 6.6 percent of the coal; the specific weight of the tar is 1.089; the oil content in the tar is 47.5 percent; the content of phenol is 6.3 percent; the yield of phenols from the coal is 0.42 percent. The yield of crude benzene is 1.5 percent; its toluene content is 16.4 percent.

(5) The slightly metamorphosed long-flame coals of the Lisichanskiy Rayon of the Donbass were investigated in detail by M. V. Gofman and I. A. Kopeliovich. A charge of 85 percent long-flame coal and 15 percent PZh coal was selected for tests under industrial conditions. In a plant without a cleaning shop, 1,030 tons of coal were coked (65 ovens were charged). The test charge contained W^F , 5.3 to 6.0 percent; AS , 8.32 to 11.30 percent, VS , 37.2% to 39.20 percent; SS , 4.31 to 4.54 percent.

The result was coke with a drum specimen of 278 kilograms and with a 78.2-percent yield (above 25 mm) in the "mikum" drum.

The yield of coke gas was 390 cubic meters per ton of dry coal. The gas had the following composition: H_2S , 1.8 percent; CO_2 , 5.1 percent; C_mH_n , 2.4 percent; O_2 , 0.8 percent; CO , 9.2 percent; CH_4 , 19.2 percent; H_2 , 66.0 percent; N_2 , 5.5 percent; Q_H , 4,070 calories per cubic meter; $\Gamma = 0.548$.

Output of tar was 4.5 percent of the coal, output of crude benzene, 1.52 percent of the coal; its toluene content, 19.77 percent.

(6) Experiments in coking long-flame coal were also undertaken in an experimental plant. The goal of the experiments was preparation of a large experimental lot of coke (1,000 tons) for experimentation in gas generators. In this experimental coking the composition of the charges was Lisichanskiy coal with an admixture of 30 percent of PZh coal. The drum specimen of coke was 276 to 300 kilograms. Tests in the gas generators established the expediency of using this type of coke because of its increased reactivity.

The yield of gas was 367 cubic meters per ton of dry coal; yield of tar, 3.8 percent of the coal; specific weight of tar, 1.18; content of liquid distillate in the tar, 65 percent; output of crude benzene up to 1.39 percent of the coal.

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c. Charges from Transcaucasus Coals

Considerable work in the direction of the utilization of Transcaucasus coal for blast furnace coke was carried out by Academician N. P. Chizhevskiy who proposed a method of condensing the charge by ramming. This made it possible to produce coke from a charge with a very considerable proportion of poorly caking Tkvibuli coal. The properties of the Tkvarcheli and Tkvibuli deposits, the two main deposits of the Transcaucasus, were determined by extensive laboratory experiments and industrial coking.

Tkvarcheli coal can be coked and gives a volatile substance yield corresponding to PZh type coal: V_E , 35.03 percent; thickness of plastic layer, 28 mm; shrinkage, 15 mm. Tkvibuli coal, on the basis of the same indexes, approaches gas and long-flame coals: V_E , 41.8 percent; thickness of plastic layer, 10 mm; shrinkage, 55 mm.

It has been established that a charge consisting of 50-60 percent of Tkvarcheli coal combined with 40-50 percent of Tkvibuli coal can produce tough coke which corresponds to metallurgical coke in its basic characteristics. Experiments in battery coking of these coals in the ratio of 50:50 percent were conducted during a 17-hour coking period. Coking was continued for a long time, thus establishing all the properties characterizing the output and quality of the coke and the chemical products of coking and obtaining data on the technological method of coke-oven operation.

If the temperature at the heating partitions is brought up to 1,350-1,360 degrees, well-fused, compact, homogenous, metallurgical coke is produced, characterized by uniformity in the size of the pieces and with a drum specimen of 315-325 kilograms. The yield of coking products are as follows: coke (gross amount), 66.15 percent; metallurgical coke, 95-97 percent of the gross amount; tar, 3.3 percent; crude benzene, 1.14 percent; ammonia, 0.184 percent; coke gas, 350 cubic meters per ton of dry coal, with a $Q_H = 4,000$ calories per cubic meter.

A brigade of the Ukraine Institute of Metals carried on experimental smelting for 10 days in a blast furnace operating on coke from Transcaucasian coal. The result indicated that this coke is suitable for in blast furnaces with a volume of 600-700 cubic meters. This shows that the expediency of producing coke from slightly metamorphosed coal which was established for Donets coal can also be applied to coal in other deposits.

ADDITIONAL RAW MATERIALS FOR
THE COKING INDUSTRY FROM
GAS COAL AND LONG-FLAME COAL

P. A. Muller made calculations in the UKhIN on the effectiveness of enriching the charge in one coke-chemical plant. Equal amounts of a normal charge without gas coal, and a modified charge with gas coal, were set as a basis for comparative calculations, since modification of the content of the charge greatly affects the yield of all coking products. Questions concerning selection of one or another type of charge are greatly clarified by this. Under such circumstances changes in production cost for different charges were calculated within the scope of yearly volume of production.

Procurement calculations were compiled on the cost per ton of coal for the charges in question and corresponding calculations were made on the production costs of each of the coking products. It was established that the

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savings from operating with a gas-coal charge are so high that if entirely applied to the coke it will result in a reduction of approximately 2 percent in the production costs of coke. If the difference in the output prices of coal, according to list prices, is taken into consideration, then the reduction in the production costs of one ton of coke is more than 10 percent of the actual production costs of coke.

Calculations on the effectiveness of introducing gas coal into the content of the charge of another coke-chemical plant were based on the principle of the equality of the volume of the coke being produced. Production costs of each of the products obtained in coke-chemical plant shops in operations with different charges were calculated and the amount of saving resulting from the introduction of gas coal into the charge was determined. Resulting calculation on the production cost of coke established that it had decreased 10.85 percent from the original amount

The volume of production with a gas-coal charge varies for different products. This is evident from the following (in percent: normal charge assumed to be 100 percent):

Coke	94.4
Gas	117.7
Chemical products (as a whole)	108.9
Gross plant production	101.4

The reduction in coke production is compensated for by the rise in the production of coke gas and chemical products to such an extent that gross plant production from a gas-coal charge is 1.4 percent higher than that from a normal charge. It has been established that with the conversion of the 14 largest coke-chemical plants to the new charge, the construction of two new coke batteries will be required to compensate for the loss of coke in connection with the increased output of volatile substances.

Different investigators have worked for a number of years on the trend towards the use of gas coal for coking. Development of the new trend in the composition of charges of coke-chemical plants may be well illustrated by data on coke-chemical plants in the South. These plants operated on Donets coal and from 1931 to 1935, inclusive, the yield of volatile substances increased only a total of one percent as follows:

	<u>VE, %</u>
1931	23.67
1932	24.28
1933	23.26
1934	24.42
1935	24.60

A change was to be noted, starting in 1936 - 1937, when the use of gas coal for coke-oven charges began to increase. Figures for this period follow:

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	<u>Volatile Substances</u> <u>VC, %</u>	<u>Percent of 1936</u>
1936	24.72	100
1937	25.26	102.2
1938	25.61	103.6
1939	26.28	105.5
1940	26.48	107.1
1945	27.50	111.2

Before 1936 the content of a coke-chemical plant charge was characterized by an insignificant amount of G coal and a uniform combined amount of PZh and G coals which yield a high amount of volatile matter. This is indicated in the following table:

	<u>Percent of Charge</u>		
	<u>1933</u>	<u>1934</u>	<u>1935</u>
PZh	46.55	46.51	44.58
G	0.14	0.41	1.54
Total of PZh and G	46.69	46.98	46.12
K	30.22	30.73	32.20
T and PS	22.49	22.29	21.68
Total	100.00 <u>[sic]</u>	100.00	100.00

Starting in 1936 there was an increase in the relative amount of coals with a high yield of volatile substances in coke-chemical plant charges:

	<u>Percent of Charges</u>					<u>1st Quarter</u> <u>1949</u>
	<u>1936</u>	<u>1937</u>	<u>1938</u>	<u>1939</u>	<u>1940</u>	
PZh	45.60	50.29	50.79	50.92	51.30	44.3
G	1.99	2.57	3.36	6.00	7.56	13.8
Total of PZh and G	48.59	52.86	54.15	56.92	58.86	58.1
K	29.17	28.68	27.98	25.51	22.16	27.3
PS	22.24	18.46	17.87	17.57	18.98	14.6
Total	100.00	100.00	100.00	100.00	100.00	100.0

There are even more noteworthy changes in the composition of charges of individual coke-chemical plants. The largest plants of the South, producing the best types of Donets coke in the USSR, operate on charges with 10-20 percent of gas coal. One coke-chemical plant used a charge containing 25 percent of gas coal, and in 1939 another plant coked a charge with a mixture containing 40 percent of gas coal and 40 percent fat coal (PZh). In this case the total amount of coal with a high yield of volatile matter amounted to 80 percent. These tendencies were also reflected in the composition of charges in plants located in the East.

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Improvement in the technology of coking lengthened the period of service of the coke ovens and cut down repairs since the gas coal in the charge decreases the destructive activity of the charge to the oven. Gas coal is actually the chief means of reducing the effect of pressure from coal bulging and assures longer preservation of the coke ovens.

The output of gas has greatly increased during the time under consideration. In individual plants in the South, the gas output in recent years reached 320-325 cubic meters per ton of charge. The increase in the output of coal tar averaged 22.9 percent. The average output of crude benzene increased 51.2 percent.

Construction of new plants is planned in which coke gas and coke for different nonmetallurgical uses will be produced. These plants will use charges with a maximum amount of slightly metamorphosed coals. One of the planned coke-gas plants is expected to adopt a charge of the following composition: 40 percent G, 40 percent PZh, and 40 percent PS coal. Another plant will operate with a gas-coal charge alone. A new coke-gas plant will be constructed which is expected to use long-flame coal. Its charge will consist of 70-80 percent D and 30-20 percent PZh coal.

The theory of the processes in the thermal decomposition of coal and the formation of volatile products belongs to the most difficult and relatively slightly developed fields in coal chemistry. Investigations discussed in this book, reveal to some extent the nature of the phenomena under consideration and form a basis for the theoretical views on this question.

Still not everything has yet been clearly explained and working hypotheses which have been adopted cannot be considered as definitely covered by theory. Although the function of the coal substance in the formation of the products of high-temperature coking can be regarded as definitely clarified, nevertheless, processes of the conversion of distinct structural components and related components of the coal substance remain incompletely investigated. One must assume that the application of thermodynamic laws to the phenomena under consideration will be very fruitful. Research in the field of investigation of coal structure by physical and physicochemical methods will help to reveal the nature of the phenomena in question. The procurement of new data on structure, composition, and transformation of coal in pyrolysis is the first task for further work in this connection.

The processes of modifying the organic substance of the components of coal in thermal decomposition depend directly on conditions in the zone of pyrolysis (temperature, time, catalysts, etc.). These conditions may be considered as adequately investigated for existing types of ovens, but they have only been slightly investigated as such without the effect imposed by the peculiar construction of the ovens. The direction of the movement of the gases in the coal charge while it is being heated is the most important phase of this question. The theory expressed in the present work must be confirmed by experimentation with coal of different types. As a result of this it will be possible to secure additional data for designing new ovens in construction of which individual characteristics of different coals will be taken into consideration. A new technology adapted to coals of a low degree of metamorphism must be created by investigation in this direction. This is the second task of future work.

It is particularly important to intensify work in the practical realization of all that has been achieved by investigations. There must be a broader development of methods designed for treating all available slightly metamorphosed bituminous coal. Not one ton of such coal must be used for energy generation without preliminary treatment in coke ovens. To this end, proportions of slightly

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metamorphosed coals, particularly those with a low sulfur content, in charges of coke-chemical plants must be regularly increased and new specialized plants must be constructed. By the law on the Five-Year Plan for the restoration and development of the national economy of the USSR 1946 - 1950, provision has been made "to construct four new gas plants; to raise production of gas from coal and shale to 1.9 billion cubic meters by 1950; to expand the gas network for the transmission of coke gas in order to utilize it for industrial purposes; to create new applications of organic synthesis based on the treatment of coal."

These tasks of the national economy can be successfully and effectively solved by a more extensive use of gas and long-flame coals for coking.

New tasks confront the USSR coal industry in this connection: to increase the mining of low-sulfur gas coals in operating mines; to accelerate the construction of new mines and intensify detailed prospecting and investigation of coals of these types for development of new mine fields

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